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ABSTRACT

This study investigated the effects of three instructional strategies and student entry characteristics on student engagement and the acquisition of skills necessary for the construction and interpretation of line graphs. The strategies examined were an activity-based approach, a written simulation-based approach, and a combination of activity- and written simulation-based instruction. Students' (N=101) entry characteristics examined included level of cognitive development and spatial ability. Results indicate that: (1) no single instuctional strategy of those examined appears to be superior to the others in regard to level of graphing achievement attained by students; (2) instructional strategies consisting of activities or a combination of activities and written simulations resulted in higher levels or engagement than instruction consisting only of written simulations; (3) students classified as transitional/formal tended to score higher than concrete operational students on the graphing achievement measure; (4) spatial scanning ability showed minimal relationship to graphing achievement; and (5) although differences in engagement across the three treatment groups accounted for a portion of the variance in graphing achievement, the treatments themselves accounted for a unique portion of the variable (which was also true across levels of cognitive development). Implications based on these findings are discussed. (JN)

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Effects of Laboratory Activities and Written Simulations on the Acquisition of Graphing Skills by Eighth Grade Students

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Purpose of the Study

The purpose of this study was to investigate the effects of various instructional strategies and student entry characteristics on student engagement and the acquisition of skills necessary for the construction and interpretation of line graphs. Three approaches to graphing instruction were examined. They were: an activity based approach, written simulation based approach and a combination of activity and written simulation based instruction. Students entry characteristics addressed included level of cognitive development and spatial scanning ability.

Rationale

Graphing competence is essential to many subject areas, including science, social science, and mathematics. The importance of graphing in science is illustrated by the emphasis placed on this skill in several instructional publications (e.g., Guidry and Fry, 1968; Petty, 1975) and most of the important science curriculum projects (e.g., Minnesota Mathematics and Science Teaching Project, 1971; Science - A Process Approach, 1965).

In science we are often concerned with predicting relationships between variables and attempting to substantiate the existance of these relationships. This task may be made easier by using a line graph to display the data. Line graphs show the relationship that exists between two continuous variables, such as ambient temperature and plant growth. This is the reason line graph construction and interpretation are so important to science instruction. They are an integral part of experimentation. Graphs are also important outside the realm of scientific experimentation. They are often included in magazines, newspapers and books to help communicate information and ideas.

It is evident that line graphs are important in the science classroom, however, research suggests that line graphs are the most difficult type of graph to interpret. Peterson and Schramm (1954) found line graphs to be more difficult to interpret than either bar graphs or circle graphs. Shaw, Padilla and McKenzie (1980) investigated the line graphing skills of 625 students in grades seven through twelve. They concluded the students could not adequately deal with either line graph construction or interpretation. Furthermore they suggest that the lack of graphing competence may be a severly limiting factor in the understanding of many complicated science concepts. The importance of graphs, coupled with apparent difficiencies in graphing ability suggest the need for developing strategies to teach this important skill.

Methods and Data Sources

One hundred and one students enrolled in four, eighth-grade science classes at a surburban/rural middle school served as subjects in this study. Subjects were administered two pretests, The Group Assessment of Logical Thinking (Roadrangka, Yeany and Padilla, 1983) and the Map Planning Test (SS-3) (Ekstron, French, Harman and Dermen, 1976).

Cognitive Development

The Group Assessment of Logical Thinking (GALT), developed by Roadrangka, et al. (1983), was used to assess students' level of cognitive development. GALT is a multiple choice format, pencil and paper test requiring approximately one class period to administer. The test contains items designed to measure the following abilities: conservation of matter and length, proportional, probabilistic, correlational, and combinatorial reasoning and the identification and control of variables. The test consists of 21 items. A students' score can range from 0 to 21 correct.

The test developers report a reliability estimate of .85 (Cronbach's α) for GALT. Concurrent validity is demonstrated by a correlation of .80 between GALT and traditional Piagetian interview tasks. The reliability estimate for GALT, Cronbach's α, (Allen & Yen, 1979, p. 79), was .72 based on scores in this study.

Students were classified into two levels of cognitive development on GALT scores. Those scoring 0-8 were classified as concrete operational while those scoring 9-21 were classified as transitional/formal operational. The combined transitional/formal classification scheme was used because of a small number of students being classified as formal operational. This scheme resulted in 73 students being classified as concrete and 28 students being classified as transitional/formal. GALT scores ranged from 0-16 correct with a mean score of 6.85.

Spatial Scanning Ability

Spatial scanning ability was measured using the Map Planning Test (SS-3) from the Kit of Factor Referenced Tests (Ekstrom et al., 1976). The test consists of two parts each containing 20 questions. Three minutes are allowed for completing each of the two parts of the test. Scores can range from 0 to 40 correct. The developers provide the following description of the test:

> The examinee sees diagrammatic sections representing city maps. The streets are blocked at various points by barriers represented as circles. The examinee must plan routes bewtween given points in such a way that no roadblock need to be crossed. The task is to find the shortest available route as quickly as possible. (p. 156)

The developers reported reliability estimates ranging from .75 to .87. An alternate-forms reliability estimate (Allen & Yen, 1979, p. 77) was computed for scores obtained in this study. The two halves of the test were treated as alternate forms of the same test. This estimate was then stepped-up using the Spearman Brown formula to obtain the reliability of the entire test. The

reliability estimate for the entire 40 item test was .50. This procedure was used in lieu of an internal consistency measure because the Map Planning Test is a speeded test.

Subjects were classified into two levels of spatial scanning ability based on scores from the Map Planning Test. A median split was employed to classify students as either high spatial scanners or low spatial scanners. Scores on the Map Planning Test ranged from 0 to 32 correct with a mean of 21.2 and a median of 21.3.

Treatments

Following pretesting, three of the four classes were randomly assigned to one of three treatments. These students experienced a unit designed to teach line graphing skills. The treatment lasted approximately fifty minutes per day for a five day period. Subjects in the remaining class served as a control group. Students in the control group did not receive any graphing instruction. All subjects receiving graphing instruction were given unit objectives (see Figure 1).

Treatment one - Subjects assigned to treatment one (activity based instruction) experienced a series of seven activity based lessons designed to teach graphing skills. A sample activity based lesson is included as appendix A. Students in this group performed the following tasks:

1. Completed pre-planned laboratory exercises
2. Identified manipulated and responding variables
3. Collected data and constructed data tables
4. Prepared axes for graphing
5. Graphed the experimental data
6. Completed interpolation, extrapolation and generalizing activities.

Treatment two - Subjects in treatment group 2 (written simulation based instruction) completed seven written simulations based on the laboratory activities in treatment one. Students experiencing treatment two performed the same tasks as treatment group one, except there were no hands-on laboratory activities. Students merely read about an experiment then organized given data for graphing. Each simulation was designed to parallel the activities in treatment one as closely as possible. For example, the written simulation based upon the activity in Appendix A described the experiment and gave students the results of adding calcium chloride to water. Students did not perform the activity.

Treatment three - The third group experiencing graphing instruction (combination activity/written simulation based instruction) completed four laboratory activities and three written simulations. All lessons used in this treatment were taken from treatments one and two.

Engagement

Engagement data were collected through direct classroom observation. A time sampling procedure was used in which subjects were observed for five seconds during two minute cycles. Each class was divided into two groups to enable engagement data to be collected by one observer. Each group contained about fifteen students. Engagement measures were taken on individuals in each group on alternate days. Therefore, each student was observed every other day. Since the treatment period was five days in length, some students were observed for three class periods while others were observed for two class period.

Classroom behavior was coded as either on task or off task during the five-second observation period. On task behavior included activities such as: attending to the teacher, attending to a worksheet, collecting data, constructing

graphs, and interpreting graphs. Off task behaviors were categorized as those that were not goal directed (e.g., talking while the teacher is explaining how to conduct an experiment).

The number of on task measures made on each student was determined. By dividing this number by the total number of observations, the proportion of observed on task behavior was determined for each student. Engagement scores could therefore range from 0 to 1.

Graphing Ability

Following the treatment period all subjects were administered the Test of Graphing in Science (TOGS) (McKenzie and Padilla, 1983). TOGS is a 26 item, multiple choice test which requires approximately 40 minutes to administer. Scores can range from 0 to 26. The test measures graphing skills such as: scaling of axes, constructing best lines interpolation and describing relationships displayed by graphs. A sample item from TOGS is given as figure 2. TOGS scores were used as the measure of graphing achievement.

The test developers report a reliability estimate of .83 (Kudor Richardson-20) for TOGS. Content validity is demonstrated through a review of the test by a panel of science experts. High agreement is noted between the developers and reviewers on the keying of items to objectives and scoring of individual items. The reliability estimate for TOGS (Cronbach's α) was .77 based on scores resulting from this study.

Analysis

The main effects of instructional strategy (treatment), cognitive developmental level, and spatial scanning ability on graphing achievement and engagement were assessed by analysis of variance procedures. The main effects of these variables on graphing achievement were also evaluated through analysis of covariance preocedures with the variance in graphing achievement due to

engagement removed. The effects of possible interaction between instructional strategy and either cognitive developmental level or spatial scanning ability were also assessed by analysis of variance procedures.

Results and Conclusions

All three treatment groups receiving graphing instruction displayed higher achievement on the graphing measure (TOGS) (see Table 1) than the control group. The differences were judged statistically significant by analysis of variance procedures (Table 2). Newman-Keuls comparison procedures revealed that there were no significant differences in graphing achievement among the three groups experiencing graphing instruction. The activity based group displayed the highest TOGS score ($x = 20.07$), the written simulation the next highest ($x = 19.37$) and the combination activity/written simulation group the lowest ($x = 18.41$). Results of analysis of covariance procedures in which the variance in graphing achievement due to differences in engagement was removed, yielded similar results (Table 3).

The engagement scores of the activity based group ($x = .92$) and the combination activity/written simulation based group ($x = .90$) was significantly higher than either the written simulation based group ($x = .83$) or the control group ($x = .67$) (Table 4). The engagement of the written simulation group was significantly higher than that of the control group. This suggests that treatments involving hands-on laboratory activities resulted in higher levels of engagement than treatment composed of only written simulations.

A significant effect of cognitive development level was evidenced on the graphing achievement measure by both analysis of variance and analysis of covariance procedures. The combined transitional/formal operational group ($x =$

20.75) scored higher than the concrete operational group (x = 17.52). Significant effects of cognitive developmental level did not occur on the engagement measure.

There were no significant effects of level of spatial scanning ability on either the graphing achievement or engagement measure. However, the high spatial scanning group displayed higher achievement on the graphing measure (x = 19.10) than the low scanning group (x = 17.79). There were also no significant interactions between levels of instructional strategy and level of cognitive development or level of spatial scanning ability.

Based upon the results presented, the following conclusions appear tenable.

1. No single instructional strategy of those examined appears to be superior to the others in regard to level of graphing achievement attained by students.

2. Instructional strategies consisting of activities or a combination of activities and written simulations resulted in higher levels of engagement than instruction consisting only of written simulations.

3. Students classified as transitional/formal tended to score higher than concrete operational students on the graphing achievement measure.

4. Spatial scanning ability showed minimal relationship to graphing achievement.

5. Although differences in engagement across the three treatment groups accounted for a portion of the variance in graphing achievement, the treatments themselves accounted for a unique portion of the variance. This was also true across levels of cognitive development.

Implications and Recommendations

Results of this study indicate that the three instructional approaches to graphing instruction examined, activity based, written simulation based, and

combination activity and written simulation based, are equally effective for teaching graphing skills to eighth grade students. If the sole objective is to teach graphing skills, perhaps the written simulation approach is the method of choice. This approach requires fewer materials and equipment and less teacher preparation than the other instructional strategies. In addition, factors such as management of hands-on activities and laboratory safety do not pose a problem when using the written simulation strategy. On the other hand, if the overall objectives of the science program include mastery of laboratory skills, such as reading a thermometer or handling chemicals, instruction that includes activities would be the one of choice. It is likely that less incidental learning of this type would take place during instruction using simulations than during activity based lessons.

Another factor to consider is engagement. Activities, or a combination of activities and written simulations, resulted in less off task time than did the use of written simulations alone. Off task time often results in classroom disturbances which may in turn result in discipline problems. It is possible that the written simulations required less time to complete than the laboratory activities, encouraging off task behavior. If this is the case, an increase in the number of simulation lessons provided during the instructional unit might result in higher engagement and increased achievement.

Cognitive abilities should be taken into account when planning graphing instruction. Since the majority of students at the eighth grade level are concrete operational, teachers should anticipate problems when dealing with the abstract components of graphing instruction, such as the concept of relationships between variables. In addition, students at the transitional/formal level of cognitive development will generally outperform concrete operational students. Teachers should be aware of this difference and adjust their expectations concerning graphing achievement to reflect the cognitive abilities possessed by

their students. Perhaps a measure of cognitive development should be given to students prior to graphing instruction, or any process skill instruction. Not only would this make teachers aware of their students abilities, but might lead to the use of more appropriate instructional strategies.

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Table 1

Means Across Treatments for All Measures

Measure	Treatment							
	Activity (n = 27)		Simulation (n = 27)		Activity/Simulation (n = 27)		Control (n = 20)	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Graphing Achievement (TOGS)	20.07	4.08	19.37	3.58	18.41	3.44	14.90	3.97
Cognitive Development (GALT)	7.85	3.14	6.48	2.75	5.30	2.48	8.10	3.79
Spatial Scanning Ability (Map Planning Test)	20.59	4.01	20.44	3.06	20.00	5.36	20.70	5.87
Engagement	.82	.05	.83	.09	.90	.05	.67	.12

Table 2

Analysis of Variance Summary Table for Graphing Achievement

Source of Variation	d.f.	Mean Square	F	p
Treatment	3	76.95	6.45	.001
Cognitive Level (COG)	1	118.60	9.94	.002
Spatial Scanning Ability (SCAN)	1	29.91	2.51	.117
Treatment X COG	3	22.17	1.86	.143
Treatment X SCAN	1	5.48	.46	.500
Treatment x COG X SCAN	3	8.70	.73	.537
Error	85	11.93		

Table 3

Analysis of Covariance Summary Table for Graphing Achievement with Engagement Included as a Continuous Variable

Source of Variation	d.f.	Mean Square	F	p
Engagement	1	17.87	1.52	.221
Treatment	3	89.23	7.57	.001
Cognitive Level (COG)	1	216.46	18.37	.001
Spatial Scanning Ability (SCAN)	1	22.76	1.93	.168
Error	94	11.78		

Table 4

Analysis of Variance Summary Table for Engagement

Source of Variation	d.f.	Mean Square	F	p
Treatment	3	2143.94	32.74	.001
Cognitive Level (COG)	1	.02	.00	.989
Spatial Scanning Ability (SCAN)	1	15.41	.24	.629
Treatment X COG	3	43.21	.66	.580
Treatment X SCAN	3	57.91	.88	.454
COG X SCAN	1	2.23	.03	.853
Treatment X COG X SCAN	3	121.15	1.85	.145
Error	85	65.61		

OBJECTIVES FOR GRAPHING UNIT

After completing this unit, you should be able to:

A. identify manipulated, responding and controlled variables;

B. make a data table;

C. draw and label axes for graphing;

D. scale axes;

E. plot points on a graph;

F. make a best-fit line;

G. describe relationships shown by graphs; and

H. collect data from a graph.

Figure 1: Objectives for graphing unit.

Lisa Measured the height that a ball bounced when it was dropped. When dropped 50 cm the ball bounced 40 cm. A 10 cm drop bounced 8 cm. The ball bounced 24 cm when dropped 30 cm. The bounce was 56 cm for a 70 cm drop. A 100 cam drop bounced 80 cm.

Which of the following graphs best described this investigation?

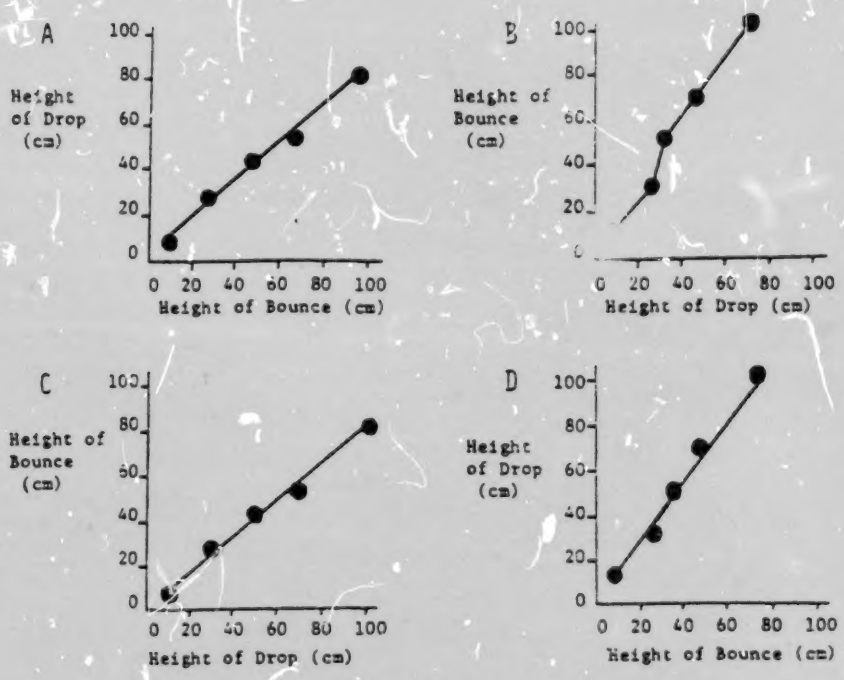


Figure 2: An item from the test of graphing in science.

APPENDIX A

A Sample Activity Based Lesson

Handout # 3a
Name_____

Today you will do an experiment. You will graph the results from the experiment. In this activity a chemical is added to water. You will see if the temperature of the water changes. Please work in groups of two.

Purpose:

This activity will allow you to practice graphing skills.

Procedures:

First gather the following items from the supply area:

4 baby food jars	calcium chloride
thermometer	grease pencil
plastic spoon	

- fill each of the baby food jars 3/4 full with water. Be sure each jar has about the same amount of water. Label jars A, B, C, and D.
- take the water temperature in jar A.
- add one level scoop of calcium chloride to jar A and stir it unitl it dissolves.
- measure the temperature of the water as soon as it dissolves.

1. Temperature of the water before_____. After_____.

2. What happened to the temperature of the water in jar A?

3. How many degrees did the temperature change when you added one scoop of calcium chloride?_____

- Repeat the above steps but this time add:
  - 2 scoops to jar B
  - 3 scoops to jar C
  - 4 scoops to jar D
- Label the data table and record your observations.

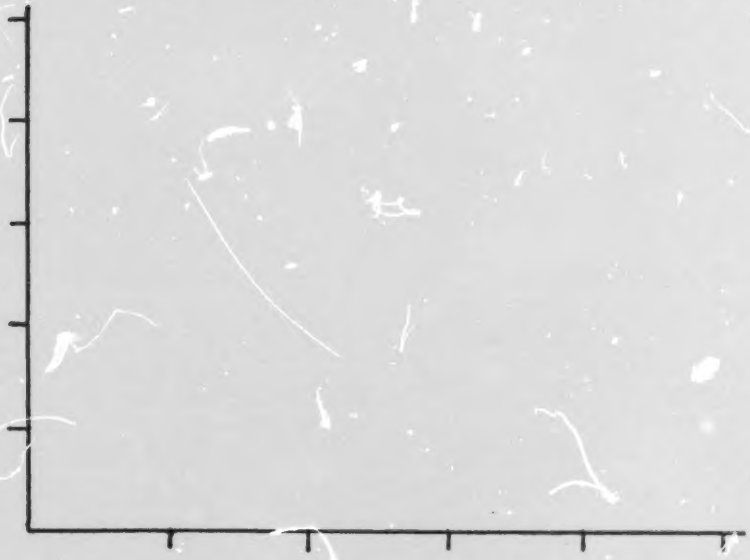
4. Did you use the same amount of water in each jar?_____

5. Did you use the same amount of calcium chloride in each jar?_____

6. Did the temperature change the same amount for each jar?_____

7. Graph the data in the data table. Be sure to follow these steps:

   - place the MV and RV on the correct axes
   - scale the axes
   - plot the points
   - draw a best fit line



8. What is the relationship between the number of scoops of calcium chloride added to the water and the change in water temperature?

9. Looking at the graph, determine the temperature change that occurred. with 3 scoops._____.

10. What do you think the temperature change would be with 2½ scoops?_____; 3½ scoops?_____.

11. Estimate the temperature change if 4½ scoops of calcium chloride were added._____.